NUMERICAL ANALYSIS OF BLAST PRESSURE PARAMETERS ON THE VEHICLE WITH AND WITHOUT WALL AS A BARRIER

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Perobohan struktur atau bangunan lama dengan menggunakan bahan letupan adalah salah satu kaedah yang digunakan dalam kerja-kerja pembinaan dan pembangunan di lokasi yang sedia ada. Malangnya, kaedah ini juga diguna pakai oleh pihak pengganas untuk mendapat perhatian pihak berkuasa tempatan atau antarabangsa. Serangan pengganas seperti ini rata-ratanya meragut nyawa apabila berlaku di tempat di mana pihak berkuasa tidak menjangka berlakunya tragedy seperti ini contohnya di kawasan kediaman termasuklah di dalam kenderaan. Oleh itu, apabila kenderaan terdedah kepada letupan ini, ia boleh memberi impak negatif terhadap struktur kereta itu dengan itu juga boleh mempengaruhi orang-orang di dalamnya. Ini kerana kebanyakan kenderaan tidak direka untuk menahan beban dinamik seperti peluru dan beban letupan, dan ia menawarkan hampir tidak ada perlindungan kepada penghuni di dalamnya kecuali kepada kenderaan-kenderaan itu untuk kegunaan khas seperti pegawai kerajaan dan pegawai kerajaan yang lebih tinggi. Oleh itu dalam kajian ini, parameter tekanan letupan dari letupan 13.61 kg (30 lbs.) TNT (trinitrotoluene) akan dinilai secara berangka. Untuk mencapai matlamat ini, ANSYS AUTODYN akan digunakan untuk mensimulasikan tekanan letupan di kawasan sekitarnya. Simulasi berangka yang pada mulanya dijalankan dalam letupan udara bebas 3D 1000 mm x 1000 mm x 5500 mm udara dan diikuti dengan pertimbangan dua lagi kes yang berbeza dengan meningkatkan domain udara 1219 mm x 3000 mm x 1112 mm jumlah udara. Susunan grid I, J, K (18, 22, 72) dipertimbangkan dalam kedua-dua kes yang tanpa sebarang halangan dinding dan dengan halangan tembok pada penyebaran gelombang letupan. Sebelum menjalankan sebarang simulasi, letupan awal bahan letupan dimodelkan. Pengesahan 30 lbs. TNT tolok yang terletak pada 5486 mm (18 kaki) dari berat caj akan disahkan dengan ujian letupan sebenar dalam penulisan sebelumnya oleh Yan et. al, (2011). Setelah pengesahan ini, bilah letupan yang sama telah diperbaiki dan digunakan untuk kes 2 dan kes 3; tanpa dan dengan dinding penghalang. Kemudian, hasil berangka diperolehi di kedudukan yang berbeza dari tolok dalam kes 2 dan case 3 dibentangkan dan dibandingkan. Keputusan menunjukkan bahawa tekanan tinggi untuk tolok 1 terletak pada jarak 1219 mm di hadapan berat cas untuk kes 3 adalah lebih tinggi berbanding dengan kes 2. Dibuktikan bahawa apabila gelombang menemui permukaan, ia dapat dilihat dan diperbesarkan tekanan . Selain itu, untuk tolok 2 terletak pada jarak 1369 mm dari pusat letupan di mana lokasi untuk kes 3; dengan dinding sebagai penghalang, tolok ini terletak betul-betul di belakang dinding. Ia menunjukkan bahawa tekanan untuk tolok ini dalam kes 3 adalah lebih rendah daripada dalam kes 2. Ini kerana apabila tangkapan dari gelombang letupan memberi kesan kepada dinding penghalang, ia akan meresap di sekitar dinding penghalang. Akibatnya, gelombang berkurang untuk beberapa jarak di belakang dinding. Selain itu, kesan tekanan letupan pada manusia di dalam kenderaan melebihi 250 kPa untuk kes 2 dan 220 kPa untuk kes 3, ini menyebabkan orang itu diambang kematian. Bagi kes 2 dan kes 3, kesan tekanan letupan ke atas manusia di luar kenderaan yang terdedah kepada tekanan tinggi yang lebih tinggi berbanding empat tolok lain kira-kira 540 kPa dan 510 kPa masing-masing. Oleh itu, orang di lokasi ini mungkin mengalami 100% kematian. Di samping itu, berdasarkan perbandingan antara dua kes yang berlaku untuk kes 2 dan kes 3, dapat disimpulkan bahawa tekanan tinggi untuk kes 3 lebih rendah daripada tekanan tinggi pada kes 2. Oleh itu, keputusan keseluruhan menunjukkan bahawa tekanan letupan dikurangkan apabila terdapat tembok penghalang berhampiran peristiwa letupan berbanding ketika tidak ada dinding pada peristiwa letupan.

ABSTRACT

Demolition of old structure or building by using explosive is one of the methods are used in construction and development works at an existing location. Unfortunately, this method also preferred by terrorist to gain attention from the local or international authorities. This kind of terrorist attack is lethal when occurred at the place where the authorities not expected to occur for example nearby the residential area including those in the vehicle. So when vehicles are exposed to this explosion, it could have a negative impact on the car's structure thus can also affect the people inside. This is because most of the vehicles are not designed to withstand the dynamic load such as bullet and blast load, and it does offer almost no protection to the occupants inside except to those vehicles for special purpose usage such as for royal and higher ranking government officer. Hence in this study, the blast pressure parameter from the explosion of 13.61 kg (30 lbs.) Trinitrotoluene (TNT) will be evaluated numerically. To achieve this objective, ANSYS AUTODYN will be used to simulate the blast pressure on the surrounding area. The numerical simulation initially conducted in 3D free air explosion of 1000 mm x 1000 mm x 5500 mm volume of air and followed by the consideration of another two different cases by increasing in air domain of 1219 mm x 3000 mm x 1112 mm volume of air. The grid arrangement of I, J, K (18, 22, 72) is considered in both cases which are without any obstruction of the wall and with obstruction of the wall on the blast wave propagation. Before running any simulation, the initial detonation of the explosive is modeled. The validation of 30 lbs. TNT of the gauge located at 5486 mm (18 ft.) from the charge weight will be verified with the actual blast test in previous literature by Yan et. al, (2011). After this verification, the same blast wedge was remapped and used for case 2 and case 3; without and with barrier wall respectively. Then, the numerical result obtained at different position of gauges in case 2 and case 3 is presented and compared. The results show that the peak overpressure for gauge 1 located at 1219 mm away in front of the charge weight for case 3 is instantaneously higher compared to case 2. It is proved that when the wave encounters a surface, it is reflected and magnified the overpressure. Besides that, for gauge 2 located at 1369 mm away from the explosive center where the location for case 3; with wall as a barrier, this gauge is located exactly behind the wall. It shows that overpressure for this gauge in case 3 is lower than in case 2. This is because when a charge from the blast wave impact the barrier wall, it will diffract around the barrier wall. As a result, the wave is lessened for some distance behind the wall. Moreover, the effect of the blast pressure on human inside the vehicle to an overpressure of 250 kPa for case 2 and 220 kPa for case 3, the person may result in threshold of fatalities. For case 2 and case 3, the effect of the blast pressure on human outside the vehicle which it exposed to the highest peak overpressure than the other four gauges about 540 kPa and 510 kPa respectively. So, the person at this location likely to experience 100 % of fatalities. In addition, based on the comparison between two cases which are for case 2 and case 3, it can be concluded that the peak overpressure for case 3 is lower than peak overpressure in case 2. Therefore, for overall results show that the blast pressure reduced when there is barrier wall nearby the blast event compared when there is no wall at blast event.

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LIST OF SYMBOLS

kPa	Kilopascal
Lbs	Pounds
Kg	Kilogram
M	Meter
mm	Millimetre
Psi	Pound per square inch
Ft	Feet
MPa	Mega Pascal
Gpa	Giga Pascal

LIST OF ABBREVIATIONS

TNT	Trinitrotoluene
RC	Reinforced Concrete
^{O}C	Degree Celcius
FE	Finite Element
CFD	Finite Volume
SPH	Mesh Free Particle
ALE	Arbitrary lagrange euler
2D	2 Dimension
3D	3 Dimension
RHT	Reidel, Hiermayer and Thoma
JC	Johnson and Cook
JWL	Jones-Wilkins-Lee
EOS	Expression of state

CHAPTER 1

INTRODUCTION

1.1 Background Study

An explosion is a sudden release of energy which it interactions with an object start with rapid chemical reactions accompanied by explosive detonation. As the shock wave propagates in the medium of the explosion product, it affects the object. With the capability to release energy, an explosion technique by using different explosive such as physical, nuclear and chemical explosions are widely used for the demolition of existing structure in development and construction works. Unfortunately, the explosion method also prefers by the terrorists to gain the attention from the authority to fulfil their request. From the record, most of the terrorist attack occurred at main attraction places with dense of civilian around. For example, the attack on World Trade Centre towers and the Pentagon, thousands of them were killed and injured on September 11, 2001 (Kontodimos, 2017). Therefore, it come an interest to protect or minimize the blast impact on the surrounding area by designing reliable building or infrastructure which is able to protect the people who lives and work nearby. Thus, blast barrier walls can be used to mitigate explosive damage to target structures such as to the civilian vehicle that would otherwise be adversely affected by an explosive charge detonation blast. In this case, the barrier walls serve two purposes which are they ensure that an explosive charge is set away from a protected object at a standoff distance and diffract blast waves to a point to mitigate the full force of the protected object's blast pressures especially to the nearby vehicle.

1.2 Problem Statement

An engineer is responsible to design structure to withstand in any possible types of different load. Although it is possible for the engineer to design the structural that able to fully withstand the blast loads but it is expensive and not economical for the civilian structure. For example, when the blast occurs at residential area, the blast pressure will cause tremendous impact to the surrounding area especially to the vehicle park nearby if only the wire fence were provided. However, if construction of reinforced concrete as a barrier wall at the boundary or residential perimeter, wall barrier can effectively reduce the blast impact and one of the effective ways of ensuring the safety of nearby civilians. For instance, the use of perimeter protection or barrier walls like fences and guard is to reduce sound pollution. But by constructing this barrier, it can have a big impact on the surrounding people as it gives the limitation and mitigates the explosion from propagating too much pressure on the object as on the vehicles behind the wall. In addition, the existing barrier wall can extend the effect of the nearby parking vehicle on the pressure reduction area.

Most of the civilian vehicles are not designed to withstand the dynamic load such as bullet, blast load and it offer almost no protection to the occupants inside except to those vehicles for special purpose usage such as for royal and higher ranking government officer. If the explosions occur at the civilian vehicle, it will propagate it pressure in the higher temperature. So when the cars are exposed to that explosion, it might give the bad impact to the structural of the car. In the worst thing, this blast also can effect to the people inside.

1.3 Objectives of the Research

The research is to consider several principal aims which is important to achieve certain expected results. To achieve the aim of this study, the following objectives have been set as:

1. To investigate the blast overpressure parameters of 13.61 kg (30 lbs.) trinitrotoluene (TNT)

2. To study the blast pressure profile on vehicle with and without wall as a barrier.

3. To observe the possible effect of blast pressure on human inside and outside the vehicle.

1.4 Scope of the Research

The scope of this research is only to focus about the blast pressure to the vehicle with or without the Reinforced concrete (RC) wall regarding to the 30-lbs TNT blast load. The research will include all this scope in order to achieve the objectives and to make sure this study is in the right flow; this are the following scopes:

1. ANSYS AUTODYN will be used to simulate the blast pressure in different cases.
2. In the numerical analysis simulation, there are three possible cases will be considered which are; blast in open space, blast without wall as a barrier and blast with wall as a barrier.
3. In the first part, the numerical modelling of RC wall subjected to 13.61 kg (30 lbs.) TNT in AUTODYN. The simulation result will be verified by the blast test on the RC wall available in the previous literature by Yan et al., (2011).
4. After that, the same blast wedge was remapped and used for the next cases which are for the case with and without RC wall as barrier.
5. The possible impact on human inside and outside the vehicle due to blast pressure.
6. The results will be compared and discussed.

1.5 Significant of the Research

Study of blast pressure behaviour and effect is important, especially to the vehicle with and without the barrier wall. Since next threat by the terrorist activities cannot be predicted and determined, by conducting this study case it may help to reduce the blast effect on the government buildings, embassy building and public places such as airport. This is because of the blast loads; exceptional case which is the man-made disasters need to be given more attention just like the cases of earthquake and wind loads. In addition, to achieve the continuity function of that structure after the explosion, the architectural and structural factors must put it together with the optimum way in building plan design.

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